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A Multi-stage Optimization Strategy Based on Fuzzy QFD and Fuzzy Swara to Adopt Blockchain Technology in the Drug Supply Chain

Naghmeh Talebi Yazdi [a*]

[a] *Department of Industrial Engineering, Payame Noor University of North Tehran, Tehran, Iran.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Introduction: Utilizing blockchain technology helps to address issues that the supply chain faces, including the intricate connections between chain network members, regulation of the distribution network, and inventory management.
Objective: To adopt blockchain technology in the drug supply chain, this study aims to offer a multi-stage optimization strategy based on Swara and QFD approaches and a zero-one nonlinear optimization problem employing a fuzzy approach.
Methods: First, field and library research was conducted to identify the barriers to the adoption of blockchain technology in the drug supply chain and the ways to overcome these barriers. The relevance of the barriers is ascertained using the fuzzy Swara approach following their refinement employing the Friedman test. The output is entered as an input in the house of quality (HOQ) rows, while the barrier-reducing techniques are presented in the columns. These approaches to reducing barriers are arranged in rows in the second phase of the house of quality.

**Corresponding author: Email: naghmetalebiyazdi@gmail.com;*

Results: Among the criteria of the barrier-reduction approach, the Performance Expectancy criterion with a score of 0.0521 has the greatest score, and the criterion of Focusing on the Major Points has the minimum score, as determined by the findings of the fuzzy Swara model. The criterion of Enhancing Transparency with a score of 0.5374 and Reducing Risk with a score of 0.4045 have the maximum, and Sustainability Performance with a score of 0.07 has the minimum score, according to the findings concerning the objectives of blockchain technology adoption in the drug supply chain. The criterion of lack of customers' awareness and attitude about sustainability and blockchain technology has the greatest score among the barriers to adoption, scoring 0.521, and the criterion of difficulty in altering organizational culture, scoring 0.033, has the minimum value.

Conclusion: Based on the results of the fuzzy house of quality, we concluded that, for the adoption of blockchain technology in the drug supply chain, the eighth (long-term perspective), first (performance expectation), and tenth (focused on the primary strengths) strategies are more beneficial. In addition, it was demonstrated that the second (Effort Expectation), ninth (information sharing), and sixth (Trust) strategies have poor rankings.

Keywords: Blockchain technology; drug supply chain; fuzzy QFD; fuzzy swara.

1. INTRODUCTION

Complexity is intrinsic to modern supply networks, which compete with other in-service consumers. Information assessment and risk management in this intricate network are nearly impossible due to globalization, various regulatory rules, and varied cultural and human behaviors in supply chain networks [1]. Nonetheless, this section's intricacy may result in delays in order processing, delivery of commodities, and order cancellation. Companies automate all of their processes to overcome these issues, and this problem alone has led to a considerable expansion in the supply chain's number of businesses and distributors. On the other hand, as the quantity of digital data continues to grow along with the number of internet enterprises, the potential for malicious attacks against database systems will also continue to increase [2]. With security in the collecting, transmitting, and sharing of accurate data, as well as in each of the steps of manufacturing, processing, storage, distribution, and sale, blockchain technology can therefore boost supply chain security [3].

Organizations are now faced with the problem of using the proper technology to take the necessary action in response to rising consumer and sustainability concerns. Diverse technologies have become a vital aspect of the supply chain in recent years. These technologies are the Internet of Things, Cloud Computing, Big Data Analytics, Wireless Sensor Networks, Radio Frequency Identification, Cyber-Physical Systems, and other information communication technologies [4]. Blockchain can serve as a pioneer in all these advancements. Increasing competitive advantage is anticipated to be a result of the blockchain, a network-based structure for bulk data storage. This technology can assist in the accurate and efficient measurement of the performance of critical supply chain management operations, leading to an increase in supply chain effectiveness [5]. Blockchain technology will therefore be useful for increasing transparency, security, authenticity, and assets' auditability in supply chains thanks to its unchangeable, decentralized, and secure qualities. In addition to increasing accountability and transparency, this technology impacts the supply chain's major goals, including flexibility, speed, quality, cost, and risk reduction [6]. In many supply chains, including those for pharmaceutical and medical products, food and agriculture, and valuable commodities, traceability is emerging as an imperative requirement and a key differentiation [7]. The pharmaceutical sector has challenges, such as the development and distribution of feigned pharmaceuticals. Improvements to supply chain management, secondary drug market control, and the application of new technologies to detect feigned pharmaceuticals are all suggested as solutions to avert these problems. Accordingly, blockchain technology can be viewed as a new instrument or platform for the drug supply chain. In contrast, drug supply chains depend significantly on centralized data management systems and require a trustworthy repository for their sensitive and important data. Improving supply chain transparency, security, and the integrity of supply chain procedures is the solution to these issues. The solution to all of these issues could be blockchain technology [8-10].

2. LITERATURE REVIEW

Jacob et al. (2022) explored blockchain technology in pharmaceutical supply chain management and operations. The results indicate an optimistic attitude towards tracking capabilities, increased efficiency, and trust building. Blockchain is beneficial when combined with other technologies, such as the Internet of Things. The study is concluded with theoretical and managerial implications and future research directions [11]. Delfani et al. (2022) considered reliability and delivery time to examine a robust fuzzy optimization for the problem of multi-objective pharmaceutical supply chain network design. The proposed model intends to optimize multi-objectives, including minimizing total costs and delivery time, while simultaneously maximizing the transportation system's reliability. A robust fuzzy optimization approach is also developed to monitor the impacts of uncertain parameters, including ordering, delivery, purchasing, and transportation costs, and the capacity of vehicles, warehouses, and distribution centers [12]. Feroz and Yousaf (2022) implemented circular supply chain management in the pharmaceutical industry. The fuzzy full consistency method (F-FUCOM) results indicate that "lack of financial resources and funding," "market challenges," and "lack of coordination and cooperation among the entire supply chain" are considered the most significant barriers, respectively. On the other hand, the results of fuzzy quality function deployment suggest "industrial symbiosis," "reverse logistics infrastructure," and "blockchain technology" as the top-ranked enablers, respectively [13]. Zakari et al. (2022) studied the role of blockchain technology in the pharmaceutical supply chain. Blockchain application areas covered in the studied articles were classified as counterfeit drug supply chain prevention, drug distribution, tracking, safety, and security. The most prevalent category was counterfeit pharmaceutical supply chain prevention, which is consistent with the primary objective of the pharmaceutical industry [14]. Sim et al. (2022) examined improving the end-to-end traceability and resilience of the pharmaceutical supply chain with blockchain. This study explored blockchain's business value to the pharmaceutical supply chain with better end-to-end traceability. Pharmaceutical manufacturers, patients, and healthcare practitioners can share data with widespread use cases of blockchain integration through six key features [15]. Mohammadesmaeil and Fattahzadeh identified criteria affecting the use of blockchain in the pharmaceutical supply chain using the meta-synthesis method during 2010-2022. Six influential criteria obtained based on selected articles and experts' viewpoints include smart contracts, simplified international transactions, supply chain identification and coordination, fraud detection and prevention in the pharmaceutical industry, permanent and safe data storage, balancing the pricing process, and reducing costs [16]. Beheshtinia et al. studied supply chain scheduling and routing in a multi-site manufacturing system. The study proposed a mathematical model and a novel genetic algorithm based on the reference group concept in sociology. The results indicated that the reference group genetic algorithm outperforms the outputs obtained from the real-world mode [17]. Meidute-Kavaliauskiene et al. (2022) discussed blockchain integration and prioritization of deployment barriers in the blood and drug supply chains. The results showed that business owners' unwillingness was the highest priority among the nine obstacles. Additionally, blockchain implementation for blood and drug supply chain management requires more payment [18]. Jadhav et al. reviewed a blockchain-based healthcare supply chain. This study provided a thorough overview of the literature on how blockchain changes how healthcare supply chains operate. They reviewed 61 articles from 2019 to 2021 highlighting various difficulties with conventional healthcare supply chains. Finally, this study explored the various obstacles and opportunities of a blockchain-based healthcare supply chain [19]. Jraisat et al. (2022) explore the role of blockchain technology integrated with reverse supply chain networks in sustainability. This study is one of the few efforts to investigate blockchain technology integrated into reverse supply chain networks for sustainable performance, contributing to the theoretical and practical knowledge of supply chains in emerging economies. As stakeholders involved with national plans and projects, all types of actors can adopt the new framework [20]. Sazvar et al. studied the design of a sustainable closed-loop pharmaceutical supply chain in a competitive market by considering uncertain demand, manufacturer brand, and waste management. The study provides sensitivity analysis and managerial implications. Numerical results suggest that the proposed classification of reverse flows leads to proper waste management, earning income, and reducing disposal costs and raw material consumption. Furthermore, competition also increases pharmaceutical supply chain performance and improves the supply of products to pharmacies [21]. Dione et al. explored the antimicrobials supply chain and delivery in Ugandan smallholder livestock production systems. This research indicates that the selection of a drug by veterinary practitioners was mainly associated with the past success of the drug and the financial capacity of the client (farmer) to cover the treatment costs. Many veterinary practitioners were not conversant with the country's veterinary drug policies. Veterinary practitioners in the Lira district were more knowledgeable about antibiotics and antimicrobial resistance compared to Mukono and those serving primarily small-scale farmers than large-scale smallholders. The study also identified several supply chain constraints as the potential stimuli for antibiotic misuse contributing to antimicrobial resistance [22]. Mueen Uddin et al. investigated blockchain-based architectures and challenges for drug traceability. This study provides an overview of product traceability issues in the pharmaceutical supply chain and envisages how blockchain can provide provenance, flexibility, integrity, traceability, and a feasible solution to mitigate counterfeit medications. In addition, the study also proposes two blockchain-based decentralized architectures, Hyperledger Fabric and Besu, to satisfy essential requirements for drug traceability, including privacy, trust, transparency, security, authorization and authentication, and scalability [23]. Babaee Tirkolaee et al. researched fuzzy decision-making and sustainable-reliable supplier selection in multi-objective programming for two-echelon supply chain design. The objectives include minimizing the total cost of the supply chain, maximizing the weighted value of the products considering the suppliers' preferences, and maximizing the supply chain's reliability [24]. Andalib Ardakani et al. studied a fuzzy multi-objective optimization model to design a forward-sustainable supply chain network. The results were reported in fuzzy form, and three elements were presented. These values were obtained for two months for each decision variable. Moreover, some parameters were analyzed for model validation and feasibility. The results demonstrated that there is a balance between the three elements [25]. Abbas et al. investigated a novel blockchain and machine learning-based pharmaceutical supply chain and recommendation system for the smart pharmaceutical industry. According to statistics, US pharmaceutical companies report business losses of about 200 billion dollars annually due to counterfeit drugs. The World Health Organization survey indicates that every tenth drug consumed is counterfeit and of low quality in underdeveloped countries. Therefore, a tracking system for drug delivery at each stage is required to solve the counterfeiting problem. Blockchain has full potential for supply chain process management and tracking [26]. Roshan et al. investigated a two-step approach to managing the agile pharmaceutical supply chain with product sustainability during a crisis. This study examines crisis management in pharmaceutical supply chains using three objective functions: minimizing total network cost, minimizing unmet demand, and maximizing social responsibility satisfaction. The study also considers perishability and sustainability with demand uncertainty [27].

3. MATERIALS AND METHODS

In terms of purpose, the current study is applicable. Since the research findings can be employed to recognize the obstacles to blockchain adoption in the drug supply chain and offer solutions to overcome these obstacles. In terms of methodology, the current research is a descriptive survey since it provides recommendations for enhancing drug supply chain services in addition to summarizing the existing situation. Twenty experts in the province of Tehran's health and medicine supply made up the statistical population of this study. A non-randomized, intentional, and judgmental sampling strategy was used in this investigation. Library approaches were employed to gather data, particularly the review and analysis of papers and documents accessible in Latin, authoritative scientific journals in the field of literature, and records of the research topic. Additionally, data was gathered using questionnaires, expert interviews, and the field technique in the field of research. In this study, data were collected via a questionnaire. The first questionnaire, created in the form of a Likert scale, was designed to refine better the obstacles to incorporating blockchain technology in the drug supply chain and ways to overcome them. The second questionnaire relates to the previous stage's weighing of barriers and refined strategies. The fuzzy Swara approach is intended to be utilized for weighing these barriers and strategies. The third questionnaire focuses on the connection between hurdles to technology adoption in the drug supply chain and measures to decrease these hurdles. The fourth questionnaire focuses on the connection between methods to decrease hurdles to

Table 1. Related literature on blockchain technology for supply chain

Author	Year	Integration	Sustainabihity performance	Flexibility	Risk	Transparency	Drug supply chain	Blockchain	Method
Jacob et al.	2022		✓	✓				✓	Content analysis
Delfani et al.	2022			✓			✓		Genetic Algorithm (NSGA-II) and Multi-Objective Particle Swarm Optimization (MOPSO)
Feroz and Yousaf	2022						✓		Fuzzy multi-criteria decision-making technique
Zakari et al.	2022						✓	✓	systematic review
Jadhav et al.	2022					✓	✓	✓	Literature review
Sim et al.	2022		✓				✓	✓	Literature review
Mohammadesmaeil and Fattahzadeh	2022	✓					✓	✓	Meta-synthesis method
Beheshtinia et al.	2022						✓		Genetic Algorithm (NSGA-II)
Meidute-Kavaliauskiene et al.	2022						✓	✓	MARCOS method
Jraisat et al.	2022		✓					✓	A qualitative research
Dione et al.	2021		✓				✓		Univariable analyse and a backwards stepwise selection Generalized Linear Models
Sazvar et al.	2021						✓		Meta-heuristic optimization algorithms
Mueen Uddin et al.	2021	✓		✓		✓	✓	✓	Literature review
Babaee Tirkolaee et al.	2020		✓				✓		FANP and DEMATEL and TOPSIS
Abbas et al.	2020			✓			✓	✓	Machine learning
Andalib Ardakani et al.	2020	✓	✓				✓		fuzzy goal programming approach
Roshan et al.	2019		✓				✓		Multi-objective decision-making
Present Study	2022	✓	✓	✓		✓	✓	✓	Fuzzy Swara and Fuzzy QFD

Table 2. Verbal variables and fuzzy numbers within the questionnaire associated with fuzzy Swara

Verbal expression	Triangular fuzzy numbers
Equal importance	1, 1, 1
Relatively low importance	0.67, 1, 1.5
Little importance	0.4, 0.5, 0.67
Very little importance	0.286, 0.33, 0.4
Extremely low importance	0.22, 0.25, 0.286

Table 3. Verbal variables and fuzzy numbers presented in the QFD section [28, 29]

Verbal variables	Fuzzy numbers
Very High	(10, 9, 8)
High	(8, 7, 6)
Medium	(6, 5, 4)
Low	(4, 3, 2)
Very low	(2, 1, 0)

incorporating blockchain technology in the drug supply chain and the objectives of using blockchain technology in the drug supply chain. Seven levels, from extremely important to very insignificant, make up the Likert scale in the questionnaire connected to the refinement of the barriers to the adoption of blockchain technology in the drug supply chain and the solutions to remove these barriers. Tables (2) and (3) summarize the verbal variables and fuzzy numbers in the questionnaires. Experts' comments have been used to evaluate the surveys' face validity, and any misunderstandings have been scientifically cleared up. Questionnaires concerning the refining of impediments to the adoption of blockchain technology in the medicine supply chain and ideas to decrease these barriers were utilized to measure reliability. In the questionnaire regarding the obstacles to the adoption of blockchain technology in the drug supply chain, Cronbach's alpha coefficient was 0.83, while it was 0.80 in the questionnaire regarding the strategies to decrease the obstacles to the adoption of blockchain technology in the drug supply chain. Hence, the questionnaires' reliability was confirmed.

The following are the primary causes for the usage of fuzzy values in the second section of the questionnaires' measurement ranges: Organizational experts or decision-makers, QFD model, and decisions. Quantitative and qualitative variables play a role in decision-making. When utilized to include qualitative factors, quantitative procedures based solely on mathematical data have limitations. These factors, on the other side, are crucial in establishing strategy decisions. The connection between WHATs and HOWs is typically ambiguous and unclear in the QFD model. This is because the QFD model doesn't have a way to convert what into hows. Each what is typically converted into a how in a subjective, qualitative, and inaccurate manner. This results in the values of the favored alternatives not being frequently calculated precisely and explicitly in accordance with the definition of the characteristic applied to them. Due to the qualitative nature of decision-making, however, decision-makers cannot articulate their interests and opinions with precision. Therefore, the assessments or alternatives have been expressed as verbal concepts to obtain a more precise estimation [29]. Fig. 1 illustrates, in general, the stages of research execution.

3.1 Friedman Test

It is a non-parametric test similar to the analysis of variance with multiple measurements within the group and is employed to compare the average rankings of *k* variables (groups). As follows, the statistical assumptions H0 and H1 are formulated: The refutation of the null hypothesis indicates a statistically considerable difference between the variables (groups).

H0: The average position of obstacles associated with sustainable services is identical.

H1: The average position of obstacles to sustainable service design is different.

Fuzzy numbers: In modern mathematics, there are various applications for the set of fuzzy numbers. Various fuzzy numbers can be utilized depending on the context. Triangular and trapezoidal fuzzy numbers are typically employed in practice. Due to their calculation simplicity, triangular fuzzy numbers (T.F.N.) are frequently utilized. Three points can be used to depict triangular fuzzy numbers, including I, M, and U. The four primary mathematical operations of two triangle fuzzy numbers and the membership function of a triangle fuzzy number can be illustrated as follows:

Table 4. Membership function of a triangular fuzzy number and four fundamental mathematical operations of two triangle fuzzy numbers

Four basic mathematical operations of two fuzzy triangle numbers			Membership function of a triangular fuzzy number
Operation	**Formulation**	**Results**	$\mu_M(x) = \begin{cases} \frac{x-1}{m-1}, & 1 \le x \le m \\ \frac{u-x}{u-m}, & m \le x \le u \\ 0, & Otherwise \end{cases}$
Summation	A+B	$(l_1+l_2,\ m_1+m_2,\ u_1+u_2)$	
Subtraction	A-B	$(l_1-l_2,\ m_1-m_2,\ u_1-u_2)$	
Multiplication	A×B	$(l_1\times l_2,\ m_1\times m_2,\ u_1\times u_2)$	
Division	A/B	$(l_1/l_2,\ m_1/m_2,\ u_1/u_2)$	

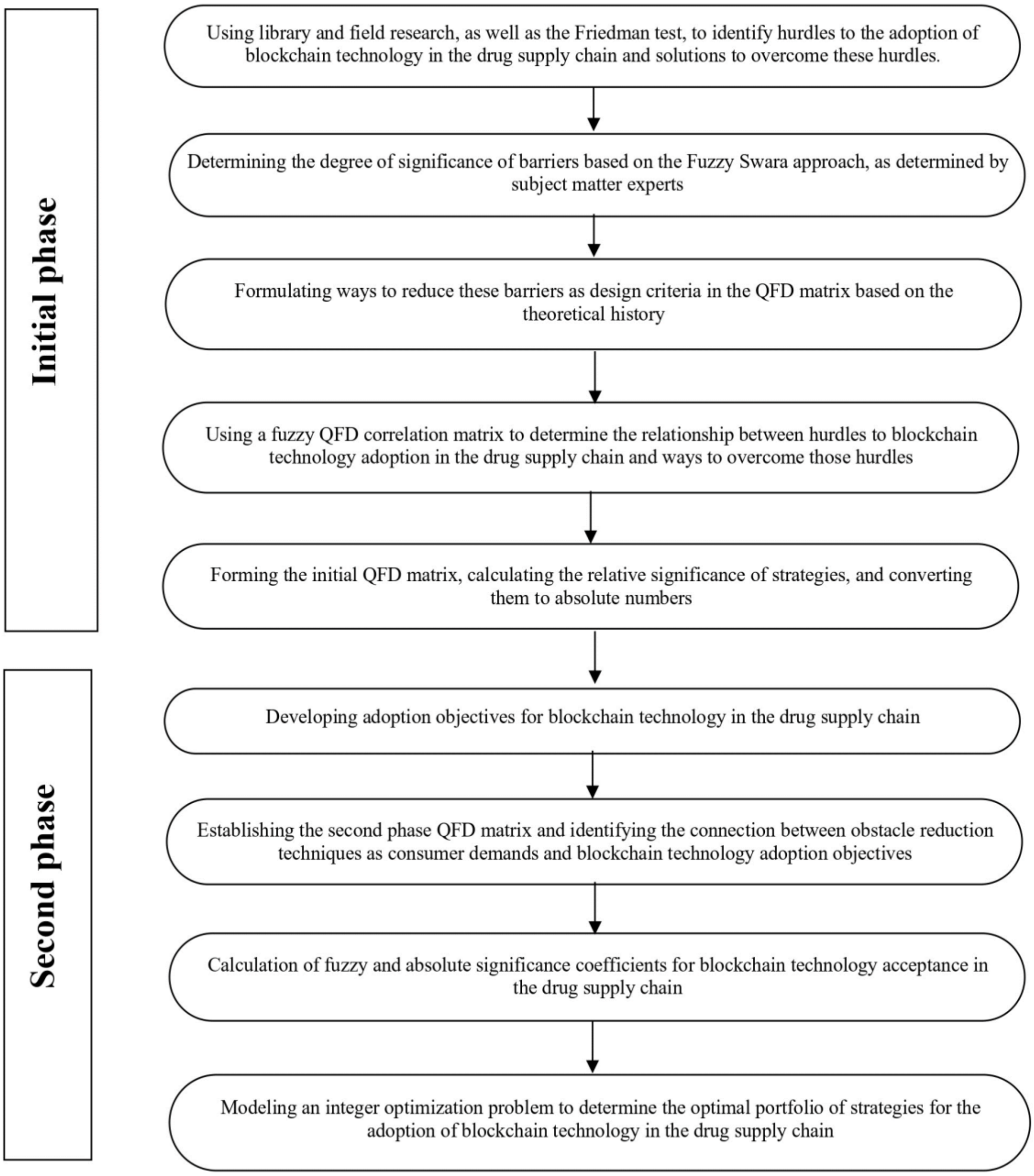

Fig. 1. The proposed implementation process for conducting research

3.2 Fuzzy Swara Method

Swara is one of the innovative ways of multi-criteria decision-making utilized in 2010 to produce an acceptable method for analyzing the differences between criteria [30]. Compared to the AHP or ANP method, this method is straightforward and less complicated. The fuzzy technique is utilized whenever respondents' comments are ambiguous, or there is inadequate information. The experts are requested to rank the relevance of each criterion in relation to the previous one after the criteria have been categorized by importance in this method. The relative weight of the criteria will be determined based on their respective importance, and the ultimate weight will be determined in the subsequent steps [31]. The following stages can be employed to demonstrate in detail how the fuzzy Swara technique is used to determine the relative weight of the criteria:

1- Sorting the criteria in descending order and determining the importance of factor j compared to the previous factor (j-1) with higher importance.

2- Calculation of the *k* value employing the following relationship:

$$\tilde{k}_j = \begin{cases} \tilde{1}, & j = 1 \\ \tilde{s}_j + 1, & j > 1 \end{cases}$$

3- Calculation of *q* value by employing the following relationship:

$$\tilde{q}_j = \begin{cases} \tilde{1}, & j = 1 \\ \dfrac{\tilde{x}_j - i}{\tilde{k}_j}, & j > 1 \end{cases}$$

4- Calculation of the weight of the criteria employing the following relationship:

$$\widetilde{w}_j = \frac{\tilde{q}_j}{\sum_k^n = 1\tilde{q}k}$$

3.3 House of Quality Matrix

The house of quality matrix has been used as the foundation for the current research's two-stage procedure of developing QFD. Fig. 2 depicts the structure and steps for completing the house of quality matrix in executing these two steps.

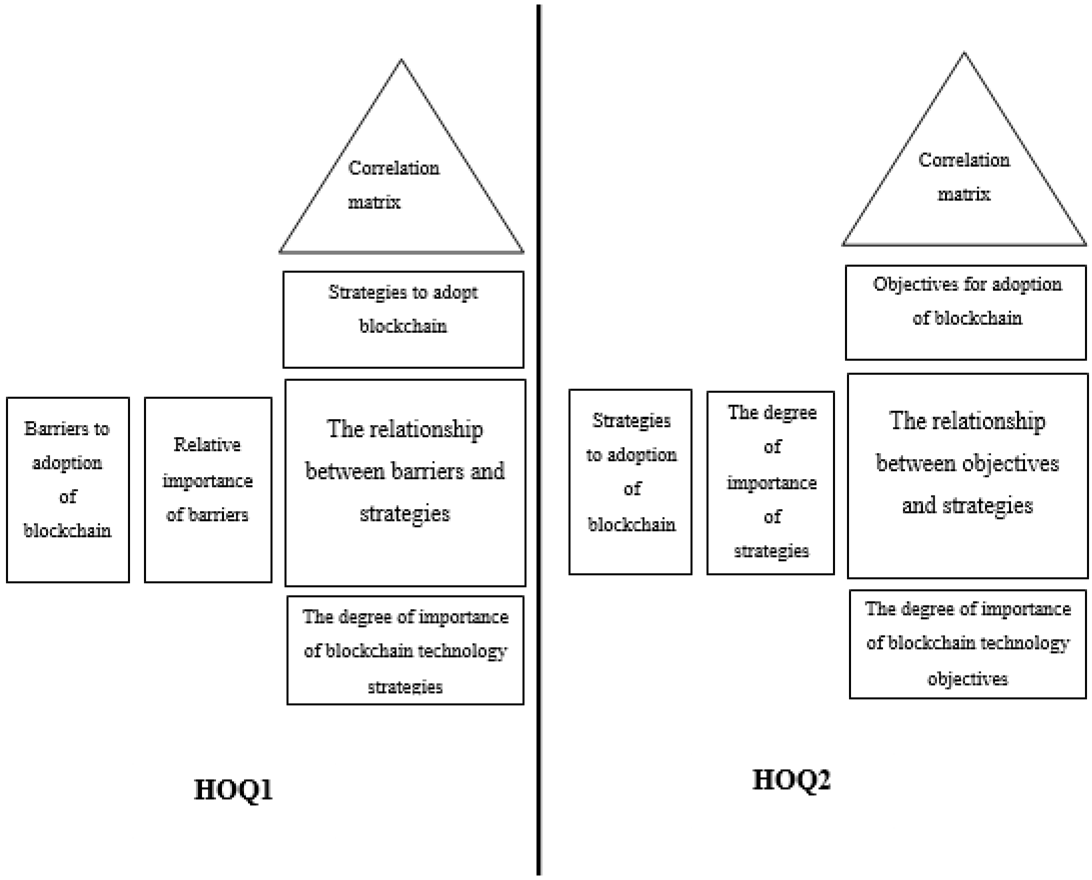

Fig. 2. House of quality matrix

Step 1. Determining the requests/WHATs: Two sorts of WHATs are defined in the model provided in this study. The first category of WHATs is attributed to HOQ1 (barriers), and the second category of WHATs is attributed to HOQ2 (strategy priorities). The second set of WHATs will be moved from the HOQ1 model to the HOQ2 model, which are hows of the HOQ1 model.

Step 2. Establishing the relative significance of WHATs: To determine the level of the relative significance of barriers or WHATs in HOQ1, this step is only calculated once. The fuzzy Swara approach was utilized in this study to determine the relative weight of barriers. In reality, the first step of the house of quality will take its input from the fuzzy Swara's output.

Step 3. Strategies identification: As previously stated, the strategies were acquired using library and field research.

Step 4. Identifying the connection between barriers and strategies: Determining the extent of the connection between whats and hows involves assessing the effectiveness of each HOWs on each WHATs. At this point, the connections between " WHATs " and "HOWs" are determined using the following formula by selecting the desired factors.

$$Score = \{S_{ij}, where\ i = 1,2,\dots,k;\ \ j = 1,2,\dots,m\}$$

$$S_{ij} = \frac{1}{n} \otimes \left(S_{ij1} \oplus S_{ij2} \oplus S_{ij3} \oplus \dots \oplus S_{ijn}\right)$$

K: WHATs or hurdles number. In this study, this number is ten.
M: It indicates the number of hows or strategies. In this investigation, there are ten strategies.
N: It represents the total number of responders. In this study, sixteen experts responded to the questions.

Step 5. Calculating the weight of each HOW: The formula for calculating the weight of each strategy or HOWs is as follows:

$$Weight = \{w_j, \qquad where\ \ j = 1,2,\dots,m\}$$

$$W_j = \frac{1}{k} \otimes \left[(S_{j1} \otimes w_1) \oplus \dots \oplus (S_{jk} \otimes w_k)\right]$$

The following formula is used to calculate the final weights of the strategies using the fuzzy weights derived from the above equation.

$$F = \frac{a + 2b + c}{4}$$

Determining the relationship between HOWs: It is essential to assess the severity of the positive or negative influence of the development of one HOW on others. The positive overlapping between the strategies is examined in this study and within the ceiling of the house of quality using the pertinent questionnaires responded by the experts.

Selecting the appropriate strategy: To maximize each strategy's participation in the development of blockchain technology, the current research's last phase involves studying and selecting the best and most effective implementation options. As previously stated, it is vital to select strategies that can achieve a balance between strategies and objectives. It should be mentioned that the QFD framework employs a variety of optimization techniques for appropriate strategies. These techniques include zero-one or quadratic linear, linear, mixed integer, and ideal programming. To choose effective strategies, the zero-one linear programming method is employed in this study. The ceiling of the QFD framework demonstrates the correlation between strategies, indicating that certain strategies can simultaneously save substantial expenses. During strategy selection, cost reductions are realized by simultaneously executing important strategies. Consequently, data on cost savings are obtained among QFD team members [32, 33]. We will attempt to identify the ideal portfolio of strategies by expanding a zero-one nonlinear optimization issue after gathering optimization-related data.

4. RESULTS AND DISCUSSION

4.1 Refinement and Identification of Variables Associated with Obstacles to Blockchain Technology Adoption in the Drug Supply Chain

Table 5 displays the average ranking of the hurdles to the adoption of blockchain technology in the drug supply chain.

Table 5. Variables associated with acceptance hurdles, objectives, and strategies of blockchain technology in the drug supply chain with a literature review

		Barriers to blockchain adoption	
1	Lack of proper government regulation and regularity uncertainty	Many countries are not yet prepared to accept blockchain technology. Consequently, they lack appropriate regulations. In addition, due to the absence of appropriate legislation for blockchain adoption, all stakeholders are uncertain about these restrictions.	[4, 34, 35]
2	Lack of interoperability & standardization	The inability of many blockchains to function due to the absence of a worldwide standard.	[35]
3	Lack of collaboration for consortia creation	The formation of a consortium offers the funds necessary to realize the full potential of the technology	[35, 36]
4	Lack of stakeholder awareness and ease of use	A limited number of stakeholders, including farmers, lack sufficient technological understanding, making it difficult for them to administer a blockchain-based system.	[35]
5	Security challenge	There are worries that data and information may represent open security risks, including hacking, the dissemination of misleading information, and access to sensitive data	[35, 37, 38]
6	The negative perception toward technology	Individuals may predominantly identify blockchain technology with cryptocurrencies like Bitcoin. These occurrences may be regarded as hostile actions. Hence, organizations may be reluctant to utilize public blockchain technology	[35, 39]
7	Immaturity of technology	The blockchain scalability issue is a technical manifestation of the immaturity of the blockchain. In reality, blockchain technology has trouble managing a high volume of transactions. Also, storing rising block sizes is a difficulty, and the real-world application of large data is an illustration of technological incompetence.	[35, 40]
8	Financial constraints	Organizations incur expenses when collecting information throughout the supply chain and transitioning to new systems. Additionally, incorporating sustainable practices is expensive. Financial resources are limited for organizations to accept this technology.	[8, 35, 41]
9	Lack of management commitment and support	Several administrators lack long-term commitment and support for sustainability practices via supply chain management procedures and the implementation of wrecking technology	[35, 42, 43]
10	Lack of new organizational policies for using blockchain technology	Organizations must create new acceptance rules for blockchain technology (appropriate application of technology, i.e., where and when).	[34, 35, 39, 44]
11	Lack of customers awareness and tendency about sustainability and blockchain technology	Failure of customer comprehension of blockchain technology for sustainable supply chain operations.	[34, 35, 39, 45, 46]
12	Lack of rewards and incentives	Governmental and professional entities have difficulty promoting sustainable practices and blockchain technology, or they lack reward systems to assure data integrity and encourage these activities.	[34, 35, 39, 46]
13	Lack of external stakeholders involvement	Non-participation and contradictory agendas of non-governmental organizations and connected communities to promote sustainable practices and blockchain technology.	[34, 35, 39, 43]
14	Problems in collaboration, communication and coordination in the supply chain	Insufficient cooperation, communication, and coordination between supply chain parties whose motivations/objectives and operational priorities are sometimes in conflict. These are additional obstacles to cooperation	[34, 35, 39, 47, 48]
15	Lack of tools for blockchain technology implementation in sustainable supply chains	Inadequate standards, techniques, instruments, criteria, and approaches for accepting blockchain technology and monitoring organizations' sustainability performance.	[34, 35, 39, 49, 50]
16	Hesitation to convert to new systems	The adoption of new systems necessitates the modification or replacement of existing systems. This issue may prompt organizations and businesses to exhibit resistance and skepticism.	[34, 35, 39, 51, 52]
17	Difficulty in changing organizational culture	The adoption of blockchain technology will alter the organizational culture. Organizational culture consists of norms for work culture and acceptable behavior within organizations.	[34, 35, 39, 44, 48]
18	Lack of governmental policies	Governments may resist accepting blockchain technology and sustainable supply chain procedures.	[8, 34, 35, 39, 53]
19	Market competition and uncertainty	It takes time to incorporate sustainable practices and blockchain technology. It may impact the company's market competitiveness and cause competitive hazards. Examples of uncertainty in	[8, 34, 35, 39]

		Barriers to blockchain adoption	
		this field include market needs for sustainable products, customer behavior, and future sales.	
20	Lack of industry involvement in blockchain adoption and ethical and safe practices	Absence of industry leadership in terms of ethical and safe sustainability and blockchain technology practices.	[34, 35, 39, 53]
Blockchain adoption objectives			
1	Enhancing the transparency of the supply chain	Blockchain can enable more transparent and accurate end-to-end tracking in the supply chain. This increased supply chain transparency provides more visibility to both businesses and consumers.	[7]
2	Sustainability performance	Blockchain to promote supply chain sustainability.	[54]
3	Management strengthening	Analysis of behavioral intentions and comprehension of the utility of blockchain technology in supply chain management.	[6]
4	Decreasing supply chain risk	Identifying the function of blockchain technology in attaining supply chain objectives. Blockchain can aid in reducing costs and risks while also enhancing quality.	[6, 55]
5	Supply chain integrity	Blockchain can improve flexibility, speed, and integrity of supply chains.	[56, 57]
6	Supply chain flexibility		
7	Time reduction		
Blockchain adoption strategies			
1	Social Influence	Blockchain is “social” technology. However, the situation could lead to higher intentions to use when there is increased normative pressure and a “critical mass” of users.	[58]
2	Performance Expectancy	The best predictors of technology use are performance expectation and behavioral intention. Blockchain technology offers a beneficial source of disseminated information with high precision and efficiency, thereby providing managers with additional options to enhance performance.	[58]
3	Technology Readiness	The adoption of blockchain technology requires access to the Internet and IT infrastructure. In some instances, an organization's IT infrastructure is inadequate, and access to technology is unfeasible. Individuals may link blockchain technology most strongly with cryptocurrencies like Bitcoin. These developments could be seen as destructive actions. Hence, organizations may be reluctant to utilize public blockchain technology.	[39]
4	Technology Affinity		
5	High management commitment	Top management commitment can be employed in blockchain implementation to better utilize sustainable practices in the supply chain.	[34, 58]
6	Facilitating Condition	Technical resources and organizational support are enabling circumstances that have a considerable influence on the intention to employ blockchain technology for supply chain traceability.	[59]
7	Long term perspective	To adopt blockchain technology, it should be planned in the long term and provide a proper vision.	[58]
8	Sharing information	Blockchain is a solution that includes a single source of disseminated information with enhanced information precision and efficiency, hence expanding managers' prospects.	[34, 58]
9	Technology Trust	Stakeholders in the supply chain may have varying privacy requirements and rules for information and data utilized in sustainable supply chains and blockchain technology. Data confidentiality, privacy, and economic value are crucial.	[58]
10	Effort Expectancy	Effort expectancy relates to the simplicity of utilizing technology. The Effort expectancy is closer to those of productivity and efficiency.	[58]
11	Focus on main strengths	Blockchain can offer an open information platform for all supply chain participants.	[60]

There are ten factors of obstacles to acceptance, six factors of the objectives of accepting blockchain technology in the drug supply chain, and ten factors of strategies for minimizing these barriers, with the maximum average ranking according to the Friedman test, based on the findings of a review of the viewpoints of 16 specialists in the field (Table 6). Hence, these criteria were chosen as the primary variables of the study, and all tests were conducted using their data.

4.2 Steps and Results of the Fuzzy Swara Method

4.2.1 Weighing the barriers to the adoption of blockchain technology in the drug supply chain using the fuzzy Swara method

Weighing and ranking the research criteria is the goal of this section. Ranking the criteria in order of relevance is the first phase of the FUZZY SWARA technique. For this reason, before interviewing the experts, questionnaires were given out, and the experts were requested to rank the ten most important criteria based on their viewpoints. The highest and lowest relevance of the criteria is represented, respectively, by the initial and final ranks. Initially, the indicators favored by the decision-makers are selected and ranked according to their level of significance as the finalized indicators. On this basis, the essential indications are assigned to higher categories, while the least important indicators are assigned to lower categories. In the subsequent stage, the relative significance of each index compared to the previous, more significant index was determined, and Sj represents this value. The subsequent step involves determining the coefficient Kj, which is a function of the relative significance of each index and then calculating the initial weight of each index q_j. The final weight of the indicators, also known as the normalized weight w_j, was computed in the final stage. The results of the FUZZY SWARA model are displayed in Table 7.

According to the findings in Table 7, among the criteria for the barrier reduction approach, the performance expectation criterion, with a score of 0.521, received the maximum rating, and the focusing on the important points criterion, with a score of 0.008, received the minimum rating. The criteria of enhancing transparency with a score of 0.5374 and reducing risk with a score of 0.4045 have the maximum score, and sustainability performance with a score of 0.07 has the minimum score based on the findings displayed for the objectives of blockchain technology adoption in the drug supply chain. The criterion of lack of customers' awareness and attitude about sustainability and blockchain technology has the greatest score among the hurdles to adoption, scoring 0.521, and the criterion of difficulty in altering organizational culture, scoring 0.033, has the minimum value. The criterion of performance expectancy with a score of 0.521, and the criterion of focusing on the primary strengths, with a score of 0.008, have the maximum and minimum scores, respectively, among the techniques lowering obstacles to the acceptance of blockchain technology in the drug supply chain.

4.3 Analyzing the Results of Applying the Fuzzy House of Quality (FHOQ)

The normalized weights of the barriers derived from fuzzy SWARA were established as customer requirements in the initial phase of the house of quality. In addition, the strategies were taken into account as technical prerequisites, and the weights of each strategy were determined. The following are the results of the correlation matrix between obstacles and strategies. Table 8 summarizes the findings of the first house of quality matrix and a ranking of strategies. The findings of this correlation suggest that the criterion of performance expectancy has a maximum score with a score of 0.154, while the criterion of focusing on the primary strengths has a minimum score with a score of 0.049.

In the subsequent stage, the strategies are positioned within the house of quality columns and characterized as customer requests. Additionally, objectives are positioned in the rows of this matrix. Table 9 displays the findings of the integration of house of quality matrices. In this Table, each objective and strategy are reviewed concurrently in three stages, including initial weight (a), normalized weight (b), and final weight (c). W represents the ultimate weight associated with the integration of each of the objectives and strategies.

Table 6. Refinement and selection of variables associated with barriers, objectives, and strategies for accepting blockchain technology in the drug supply chain

	Variables			
	Barriers to the adoption of blockchain technology in the drug supply chain	**Number**	**Significance**	**Average ranking**
V1	Lack of interoperability standardization	□□□□	□□□□□	□□□□
V2	Lack of management commitment and support	□□	□□□□□	□□□□
V3	Lack of collaboration for consortia creation	□□	□□□□□	□□□□
V4	Lack of agro-stakeholder awareness and ease of use	□□	□□□□□	□□□□
V5	Lack of industry involvement in blockchain adoption and ethical and safe practices	□□	□□□□□	□□□□
V6	Lack of governmental policies	□□	□□□□□	□□□□
V7	Lack of proper government regulation and regularity Uncertainty	□□	□□□□□	□□□□□
V8	Difficulty in changing organizational culture	□□	□□□□□	□□□□□
V9	Problems in collaboration, communication, and coordination in the supply chain	□□	□□□□□	□□□□□
V10	Lack of customers awareness and tendency about sustainability and blockchain technology	□□	□□□□□	□□□□
Barriers-reducing strategies to the adoption of blockchain technology in the drug supply chain				
S1	Performance Expectancy	□□	□□□□□	□□□□□
S2	Effort Expectancy	□□	□□□□□	□□□□
S3	Facilitating Condition	□□	□□□□□	□□□□□
S4	Technology Readiness	□□	□□□□□	□□□□□
S5	Technology Affinity	□□	□□□□□	□□□□
S6	Technology Trust	□□	□□□□□	□□□□
S7	High management commitment	□□	□□□□□	□□□□□
S8	Long-term perspective	□□	□□□□□	□□□□□
S9	Sharing information	□□	□□□□□	□□□□
S10	Focus on main strengths	□□	□□□□□	□□□□□
The objectives of adoption of blockchain technology in the drug supply chain				
G1	Enhancing the supply chain transparency	□□	□□□□□	□□□□□
G2	Reducing supply chain risk	□□	□□□□□	□□□□□
G3	Strengthening management	□□	□□□□□	□□□□□
G4	Integrity	□□	□□□□□	□□□□□
G5	Flexibility	□□	□□□□□	□□□□
G6	Sustainability performance	□□	□□□□□	□□□□□

Table 7. The descending sequence of barriers, strategies, and objectives for the adoption of blockchain technology in the drug supply chain

Variables					
Barriers to the adoption of blockchain technology in the drug supply chain		**Sj**	**kj**	**qj**	**wj**
V1	Lack of customers awareness and tendency about sustainability and blockchain technology	1	1	1	0.521
V2	Lack of proper government regulation and regularity Uncertainty	0.286	1.286	0.714	0.392
V3	Lack of governmental policies	0.67	1.67	0.362	0.196
V4	Lack of industry involvement in blockchain adoption and ethical and safe practices	0.286	1.286	0.286	0.147
V5	Lack of agro-stakeholder awareness and ease of use	0.4	1.4	0.259	0.123
V6	Problems in collaboration, communication, and coordination in the supply chain	0.4	1.4	0.204	0.99
V7	Lack of management commitment and support	0.4	1.4	0.126	0.078
V8	Lack of interoperability standardization	0.286	1.286	0.122	0.065
V9	Lack of collaboration for consortia creation	0.5	1.5	0.044	0.044
V10	Difficulty in changing organizational culture	0.33	1.33	0.031	0.033
Barriers-reducing strategies to the adoption of blockchain technology in the drug supply chain					
S1	Performance Expectancy	1	1	1	0.521
S2	Effort Expectancy	1.016	4.016	2.244	0.392
S3	Facilitating Condition	3.17	6.17	1.128	0.196
S4	Technology Readiness	1.016	4.016	0.849	0.147
S5	Technology Affinity	1.57	4.57	0.569	0.098
S6	Technology Trust	1.57	4.57	0.384	0.065
S7	High management commitment	1.57	4.57	0.26	0.044
S8	Long-term perspective	1.016	4.016	0.197	0.033
S9	Sharing information	1	2	0.098	0.016
S10	Focus on main strengths	3.17	6.17	0.053	0.008
The objectives of adoption of blockchain technology in the drug supply chain					
G1	Enhancing the supply chain transparency	0.423	0.521	0.668	0.5374
G2	Reducing supply chain risk	0.302	0.392	0.52	0.4045
G3	Strengthening management	0.121	0.196	0.311	0.2093
G4	Integrity	0.086	0.147	0.242	0.1585
G5	Flexibility	0.052	0.098	0.173	0.1076
G6	Sustainability performance	0.031	0.065	0.123	0.0733

Table 8. The findings of the first house of quality matrix

Factor	Weight	Value
Performance Expectancy	19.62	0.154
Effort Expectancy	8.54	0.063
Facilitating Condition	10.54	0.077
Technology Readiness	15.65	0.115
Technology Affinity	17.84	0.131
Technology Trust	10.7	0.078
High management commitment	16.64	0.122
Long-term perspective	21.05	0.144
Sharing information	6.62	0.067
Focus on main strengths	9.20	0.049
	SUM	**1**

Table 9. The results of integrating house of quality matrices

		G1			**G2**			**G3**			**G4**			**G5**			**G6**		
		a	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
S1	0.144	3.33	4.33	5.33	5.33	6.33	7.33	4.33	5.33	6.33	5.33	6.33	7.33	2.67	1.67	2.67	7.33	6.33	7.33
S2	0.063	3.33	4.33	5.33	0.67	1.67	2.67	1.67	2.67	3.67	5.33	6.33	7.33	3.33	2.33	3.33	2.67	1.67	2.67
S3	0.077	7.33	8.33	9.33	2.67	3.67	4.67	1.33	2.33	3.33	5.33	6.33	7.33	6.33	5.33	6.33	6.67	5.67	6.67
S4	0.115	4.33	5.33	6.33	4.33	5.33	6.33	5.67	6.67	7.67	3.33	4.33	5.33	5.33	4.33	5.33	5.33	4.33	5.33
S5	0.131	5.00	6.00	7.00	2.33	3.33	4.33	4.33	5.33	6.33	4.33	5.33	6.33	5.33	4.33	5.33	2.67	1.67	2.67
S6	0.078	0.67	1.67	2.67	2.33	3.33	4.33	1.67	2.67	3.67	4.67	5.67	6.67	4.33	4.33	4.33	5.33	7.33	5.33
S7	0.122	7.67	8.67	9.67	3.33	4.33	5.33	2.33	3.33	4.33	4.33	5.33	6.33	5.00	5.00	5.00	4.67	6.33	4.67
S8	0.154	6.67	7.67	8.67	4.33	5.33	6.33	5.33	6.33	7.33	5.33	6.33	7.33	0.67	0.67	0.67	5.33	6.33	5.33
S9	0.049	2.33	3.33	4.33	0.67	1.67	2.67	4.33	5.33	6.33	4.67	5.67	6.67	7.67	7.67	7.67	6.00	7.00	2.33
S10	0.067	7.33	8.33	9.33	2.00	3.00	4.00	4.33	5.33	6.33	5.33	6.33	7.33	6.67	6.67	6.67	1.67	2.67	2.33
		W1			W2			W3			W4			W5			W6		
		a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
		7.58	5.52	6.46	3.12	4.06	5.00	3.53	4.47	5.41	4.44	5.38	6.32	5.52	4.74	6.22	3.53	5.44	6.55
		20.25			12.49			13.81			16.79			16.48			15.52		
			0.320			0.197			0.218									0.220	
												0.298			0.265				

According to the preceding Table, the following is a summary of the relationship matrix between strategy and objectives.

According to the data received from the pairwise comparison by experts and managers employing the fuzzy SWARA approach provided in the previous sections, the extent of compatibility of the pairwise comparison matrices was computed to determine the significance of the objectives of blockchain technology adoption in the drug supply chain to calculate the fuzzy and definite weights in connection to the objectives of blockchain technology adoption in the drug supply chain. With a weight of 0.320, the objective of enhancing transparency has the maximum weight, while the objective of decreasing supply chain risk has the minimum weight. In the next step, it must be established which strategies are the most appropriate for accomplishing the objectives of blockchain technology adoption. It was essential to convert the relationship matrix between strategies and objectives into dephasing numbers for this purpose. In this study, fuzzy numbers were converted to dephasing using the Yager formula. The results of dephasing numbers are presented in Table 11. The matrix's dephasing numbers' row summation is represented by A_{ij}. Subsequently, the numbers in the A_{ij} column were normalized, and the finding was recorded in the R_{ij} column, referred to as the value or relative significance.

Based on the absolute significance in the preceding matrix, we can conclude that the eighth (long-term perspective) with a value of 0.127, the first (Performance Expectancy) with a value of 0.115, and the tenth strategy (focusing on the main strengths) with a value of approximately 0.5 significantly assist the objectives of accepting blockchain technology in the drug supply chain. In addition, it was demonstrated that the second (Effort Expectancy) with a value of 0.076, the ninth (information sharing) with a value of 0.081, and the sixth strategy (Trust) with a value of 0.068 had low ranks.

The extent of compatibility of the pairwise comparison matrices for determining the relevance of objectives of accepting blockchain technology in the drug supply chain was calculated to determine the fuzzy and definite weights for the objectives of accepting blockchain technology in the drug supply chain based on the data acquired from the pairwise comparison by experts and managers employing the fuzzy SWARA approach provided in Table 12. The objective of enhancing the supply chain's transparency is the most important, with an importance factor of0.320, while the objective of flexibility is the least important, with an importance factor of 0.197.

Table 10. Normalized weight of objectives

	Variables	Fuzzy weight	Final weight
G1	Enhancing the supply chain transparency	0.047	0.320
G2	Reducing supply chain risk	0.049	0.197
G3	Strengthening management	0.081	0.218
G4	Integrity	0.079	0.298
G5	Flexibility	0.048	0.265
G6	Sustainability performance	0.052	0.220

4.4 Optimization Problem

Following the collection of optimization-related data, we will develop a zero-one nonlinear optimization problem to identify the ideal portfolio of strategies. The formulation of the optimization problem is as follows:

$$Max\ f(x) = \sum_{j=1}^{n} RI_j x_j$$

$$S.t. \quad \sum_{j=1}^{n} c_j x_j - \sum_{i=1}^{n} \sum_{j>1}^{n} s_{ij} x_i x_j$$

$$\sum_{j=1}^{n} r_{ij} x_j \geq L_i \quad for \quad \forall_i$$

$$0 \leq x_j \leq 1$$

$$x \epsilon \{0, 1\}$$

j: the relative significance of strategies S_j.
X_j: is either zero or one depending on the selected strategy S_j.
If S_i and S_j are utilized simultaneously, S_{ij} represents the amount of savings on the ceiling of the house of quality.
r_{ij}: the relative significance of blockchain technology adoption objectives in the drug supply chain illustrates the influence of strategies on blockchain technology adoption objectives.
L: The lower limit of the adoption objectives for blockchain technology in the drug supply chain needs to be calculated.

Table 11. The impact of strategies on goal achievement

	G1	G2	G3	G4	G5	G6	Aij	Rij
S1	21.32	18.07	21.32	14.82	10.11	1.00	75.54	0.115
S2	21.32	9.43	6.18	14.82	19.41	0.909	51.75	0.076
S3	21.32	8.32	12.68	27.82	8.41	0.106	70.15	0.104
S4	14.82	22.43	18.07	18.07	11.62	0.866	73.40	0.108
S5	18.07	18.07	11.57	20.25	27.87	0.101	67.97	0.100
S6	19.18	9.43	11.57	6.18	24.09	0.787	46.36	0.068
S7	18.07	11.57	14.82	28.93	11.02	0.091	73.40	0.108
S8	21.32	21.32	18.07	25.68	24.01	0.087	86.40	0.127
S9	19.18	18.07	6.18	11.57	13.02	0.075	55.00	0.081
S10	21.32	18.07	10.50	27.82	10.45	0.065	77.72	0.111

Table 12. Absolute and fuzzy importance coefficient for blockchain technology adoption objectives in the drug supply chain

	Variables	Average	Final weight
G1	Enhancing the supply chain transparency	20.25	0.320
G2	Flexibility	12.49	0.197
G3	Strengthening management	13.81	0.218
G4	Integrity	16.79	0.298
G5	Reducing supply chain risk	16.48	0.265
G6	Sustainability performance	15.52	0.220

Table 13. Objectives-based strategies for using blockchain technology in the drug supply chain

Objectives	Strategy	Selected strategies	Relative significance (Rij)
Enhancing the supply chain transparency	Performance Expectancy	1,2,8,10	9.059
Flexibility	Effort Expectancy	1,3,8,10	8.076
Strengthening management	Facilitating Condition	1,7,8,10	8.049
Integrity	Technology Readiness	1,5,8,10	7.056
Reducing supply chain risk	Technology Affinity	1,4,8,10	7.025
Sustainability performance	Technology Trust	8,1,10	6.051
	High management commitment	1,7,8,10	7.030
	Long-term perspective	1,7,10	6.025
	Sharing information	1,4,5,8,10	6.095
	Focus on main strengths	1,8,10	5.023

A set of limitations are policy constraints on adoption objectives for blockchain technology (Li's lower bounds). It should be noted that considering the objectives of implementing blockchain technology in the drug supply chain, the high optimization problem is a special problem that seeks to maximize the efficiency of strategies.

According to Table (13), the appropriate strategy for achieving each specified objective can be selected. According to the findings, Performance Expectancy strategies are viewed as having a long-term perspective and focusing on the organization's primary capabilities as well as a focal point for achieving its objectives.

5. CONCLUSION

This study provides a multi-stage optimization strategy employing Swara and QFD approaches and a fuzzy approach to a zero-one nonlinear optimization issue to adopt blockchain technology in the drug supply chain. Initially, field and library research was conducted to identify the barriers to the acceptance of blockchain technology in the drug supply chain and methods to eliminate these barriers. Then, using the fuzzy Swara approach, the significance of the hurdles was established. The output was entered as an input in the house of quality rows, while the strategies to overcome these barriers were put in the columns. Strategies to decrease barriers were set in the rows of the second phase of the house of quality. In addition, the objectives of accepting blockchain technology in the drug supply chain were acknowledged as technical necessities. The criterion of Performance Expectancy, with a value of 0.3341, has the greatest score among the criteria of the strategy to reduce barriers, while the criterion of Focus on Main Points, with a score of0.0065, has the minimum score, according to the findings of the fuzzy Swara model. The maximum score has been attributed to the criterion of enhancing transparency and decreasing risk, while the minimum score has been attributed to the criterion of sustainability performance. The criterion of lack of customers' awareness and attitude about sustainability and blockchain technology receives the maximum rating among the hurdles to acceptance, while the criterion of Difficulty in altering organizational culture receives the minimum rating. The fuzzy house of quality (FHOQ) findings led us to the conclusion that the first (performance expectation), eighth (long-term view), and tenth (focused on the major strengths) strategies are more beneficial for the adoption of blockchain technology in the drug supply chain. In addition, it was demonstrated that the second (Effort Expectation), ninth (information sharing), and sixth (Trust) strategies have low rankings.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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